Investigation of magnetic field inside Belle II spectrometer

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What is Belle II

Belle II detector at SuperKEKB, e+/e- asymmetric collider, have started in springtime 2019. Key features of Belle II and SuperKEKB are:

1. High precision vertex detection (aimed for B decay)
2. Very high beam currents of 3A
3. Use of nano-beam technology
4. Target luminosity at end of experiment: $50ab^{-1}$.
5. Clean collisions

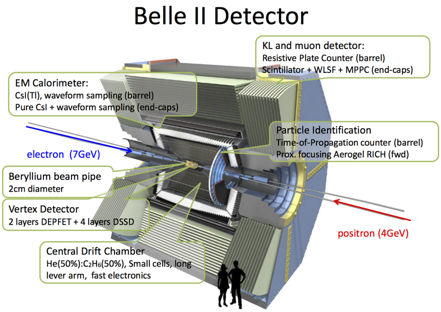


Figure: Rendering of Belle II

Belle II status and Proscpect by Zdenek Dolezal, https://indico.cern.ch/event/819524/contributions/3680714/

T. Abe *et al.* [Belle-II Collaboration], "Belle II Technical Design Report," arXiv:1011.0352 [physics.ins-det].

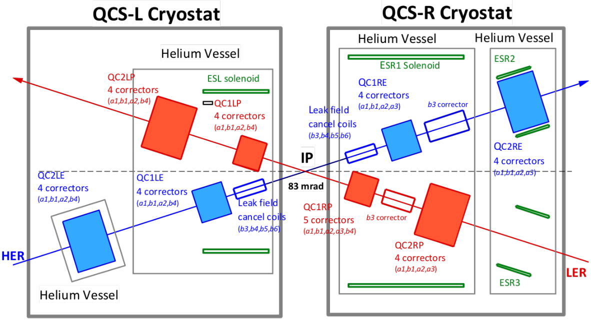
Investigation overview

To achieve high tracking performance, precise field map is necessary. Combination of following methods was used:

1. Initial Final Element Method simulation.
2. Mapping of whole tracking volume, in solenoid field only
3. Mapping of accessible volumes with of full magnetic system.

Magnet system of Belle II

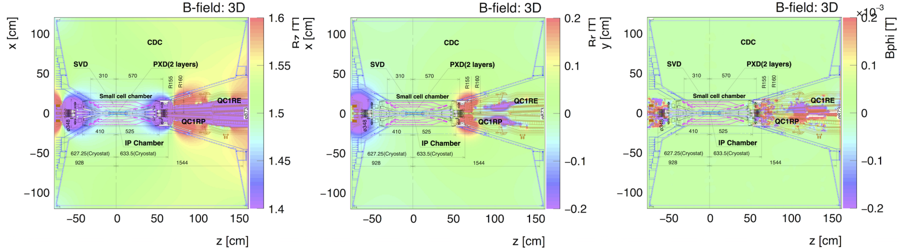
Around Interaction Point, complex magnetic system is present.



1. Superconducting solenoid, 4,4 kA, 1,5 T.
2. Superconducting final focus quadruples. Integral field gradients up to 22.91 T.
3. Compensating solenoids.

T. Abe *et al.* [Belle-II Collaboration], "Belle II Technical Design Report," arXiv:1011.0352 [physics.ins-det].

Initial simulation



(a) (b) (c)

Figure: Magnetic field strength in x-z plane from simulation (model 1A): (a) Bz (b) Br (c) Bϕ components. The Belle II detector drawing is overlayed.

Y. Arimoto *et al.*,"Three Dimensional Field Analysis for Final Focus Magnet System at SuperKEKB," Proceedings, 5th International Particle Accelerator Conference, WEPRI086 (2014).

Initial simulation and accessible regions

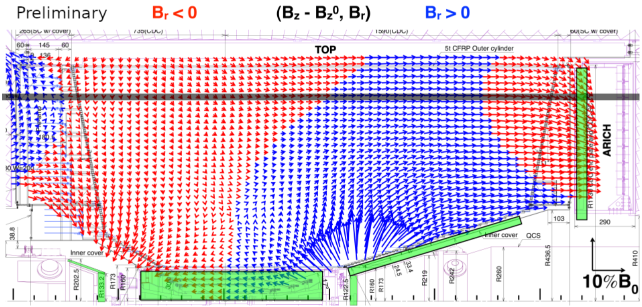


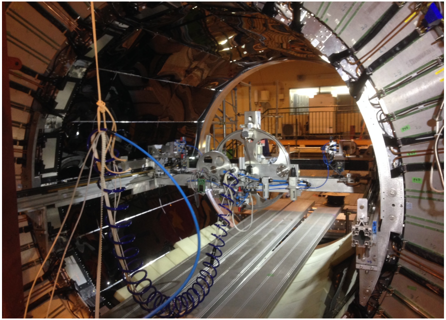
Figure: Initial estimate of field, created by accelerator development group, using Opera-3D (TOSCA). Green color highlights regions accessible when full magnetic system is present, black bar represents radial limit of whole volume measurement.

Y. Arimoto *et al.*,"Three Dimensional Field Analysis for Final Focus Magnet System at SuperKEKB," Proceedings, 5th International Particle Accelerator Conference, WEPRI086 (2014).

Cobham Technical Services, Vector Fields Software, Oxford, England, http://operafea.com/.

First measurement campaign

1. 2018 measurement covered whole tracking volume, but without beam optics magnets.
2. Mapping robot was provided by B-field mapping & Magnet support group from CERN.
3. Linear set of 34 3D Hall probes, fixed to pneumatic driven plate parallel to diameter of the main solenoid.



Dirk MERGELKUHL, "BELLE 2 - Alignment of Magnetic Field Measurement Bench in B164 Measurement date: 17-18.05.2016". https://edms.cern.ch/ui/!master/navigator/document?D:1283223467:1283223467:subDocs

F. Bergsma, H. Boterenbrood, "BsCAN3, a modular 3D magnetic-field sensor system with CANopen interface", CERN/Nikhef,

http://www.nikhef.nl/pub/departments/ct/po/html/Bsensor/BsCAN3.pdf

First measurement vs initial simulation

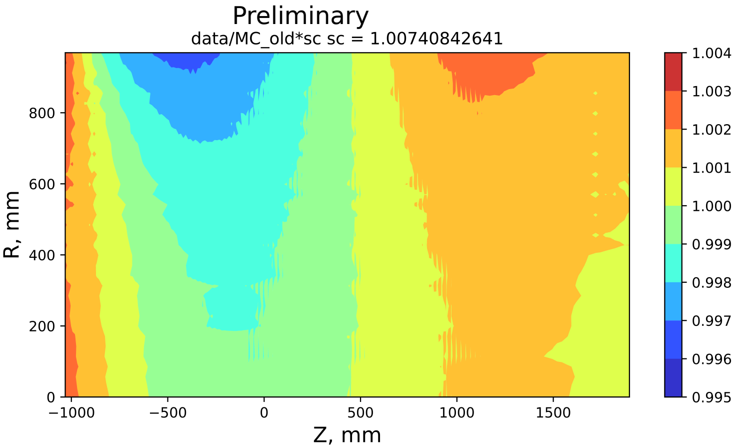
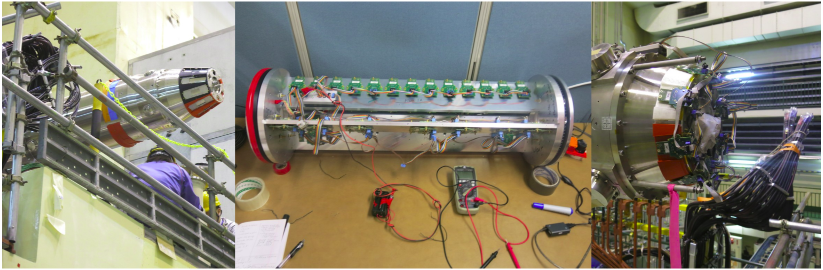


Figure: Ratio between 2016 measurement and initial simulation

Second measurement campaign



1. 2017 measurement covered full set of magnets.
2. Piezoelectric driven, robotized mapper consisted of three planar sets of 43 sensors in total.
3. Additional 46 sensors were fixed to surfaces of magnet cryostat and Central Drift Chamber using 3D printed structures.

Second measurement results

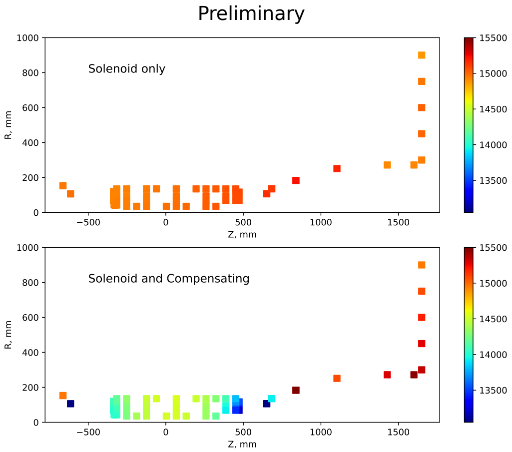


Figure: The B field generated by Belle II solenoid only and with compensating solenoids

D0 measurement quality

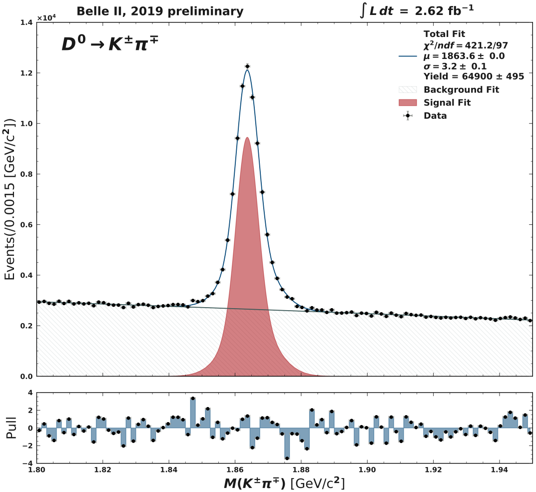


Figure: Preliminary D^0 reconstruction. Narrow peak and agreement with PDG's 1864.84 MeV indicate good B Field map and alignment.

Ongoing and future work

1. Field map in use now seems to be very effective.
2. Possible further improvements are being investigated.
3. Current effort concentrates providing map with improved description just outside of 2016 measurement volume.
    - Theta dependent pt-bias in cosmic muon events confirms measured field map at large radii
    - Precise checks are done using secondary decays of $K_S^0 \rightarrow \pi^+\pi^-$. Variation in mass distribution width is useful to investigate spatial distribution of imperfections.

The End

Acknowledgments

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- Tests of prototypes were performed in DESY, with support of AIDA2020 funds.